

For Reference

NOT TO BE TAKEN FROM THIS ROOM

Ex LIBRIS
UNIVERSITATIS
ALBERTAENSIS





Digitized by the Internet Archive
in 2018 with funding from
University of Alberta Libraries

<https://archive.org/details/antibioticsofswi00robe>

THE UNIVERSITY OF ALBERTA

ANTIBIOTICS IN SWINE NUTRITION

A DISSERTATION

SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

FACULTY OF AGRICULTURE

DEPARTMENT OF ANIMAL SCIENCE

by

ROBERT HIRONAKA

EDMONTON, ALBERTA,

APRIL, 1953

ANTIBIOTICS IN SWINE NUTRITION

ABSTRACT

Three experiments were conducted to study the addition of aureomycin, penicillin or bacitracin supplements to swine rations.

The rate of gain of pigs was generally increased by antibiotic supplementation of a ration, but responses were variable. Antibiotics in combination or in series showed no advantage over a single antibiotic supplement. Aureomycin was found to be the most effective in promoting growth. Feed efficiency was not affected to any marked degree by antibiotic supplementation of the ration. As the level of protein in the ration during the growing period was decreased, there was a trend toward slower gains whether or not an antibiotic was added to the ration.

Carcasses from pigs fed an antibiotic to 200 lb. tended to be fatter than carcasses from pigs not receiving any antibiotic supplement. Removal of the antibiotic at the end of the growing period prevented this reduction in carcass quality in two trials; however, in a third trial, carcasses from pigs fed an antibiotic to 110 lb. in weight were fatter and had a smaller area of loin than those receiving no antibiotic. Carcasses from antibiotic fed pigs shrank more in weight on cooling than carcasses from pigs not receiving an antibiotic, indicating an increased water content in the former carcasses.

Plasma lipid levels were found not to be affected by penicillin supplementation of the ration, or by different levels of protein fed. In one trial, positive correlations were found between plasma lipid levels and thickness of loin or shoulder fat, and negative correlations

with area of loin or backfat score. However, in a second trial no significant correlations were found.

Vitamin A and carotene storage in the liver was not affected by antibiotic supplement or level of protein in the ration.

ACKNOWLEDGMENTS

The writer wishes to thank Dr. L. W. McElroy, Head of the Department of Animal Science, for placing the facilities of the Department at his disposal; and to gratefully acknowledge the helpful advice of Dr. J. P. Bowland, Assistant Professor of Animal Husbandry, during the course of this study and in connection with the preparation of this manuscript. The aid of Dr. S. Zalik, Assistant Professor of Plant Science, in carrying out the statistical analysis is acknowledged.

The writer is also indebted to Mr. Jack Francis, swine herdsman at the University Livestock Farm, who cared for the experimental animals.

The cooperation of the Production Service, Canada Department of Agriculture, in scoring the pigs by Advanced Registry standards is gratefully acknowledged.

This project was supported in part by a grant from the Prairie Regional Laboratory of the National Research Council.

TABLE OF CONTENTS

	<u>Page</u>
Introduction.....	1
Review of Literature.....	3
Experimental.....	15
Experiment I - The effect of deleting antibiotics from the ration at various stages of the pigs' growth	16
Experiment II - The effect of antibiotic supplements with various levels of protein during the growing period....	27
Trial A.....	27
Trial B.....	37
Experiment III - The rate of gain and feed efficiency of swine receiving various antibiotic supplements singly and in combination as well as in series.....	48
Summary and Conclusions.....	54
Literature Cited.....	56

ANTIBIOTICS IN SWINE NUTRITION

INTRODUCTION

In Canada, which is a major producer of bacon hogs, there has been a constant evolution in feeding and management practices in the swine industry. The use of antibiotics in rations for growing pigs has been one of the most spectacular advances in swine production during the past decade. Antibiotic supplements were first used in swine rations in 1949, and most commercial rations for growing pigs now contain an antibiotic.

The discovery that antibiotics are effective in increasing the rate of growth of chicks and pigs arose out of studies on the use of vitamin B₁₂ in their rations. The vitamin B₁₂ supplements, formerly designated as APF supplements, were crude fermentation residues. It was found that certain of these APF supplements resulted in an increased rate of growth greater than that which could be accounted for on the basis of their vitamin B₁₂ content. It was demonstrated that the additional growth response obtained was a result of the presence of residual amounts of aureomycin in the supplement. Subsequently, it has been shown that many other antibiotics are also effective in increasing the rate of growth of chicks and pigs.

In the latter part of 1950, the Association of American Feed Control Officials in consultation with others concerned, adopted the names "antibiotic feed supplement", or "vitamin B₁₂ and antibiotic feed supplement" for all preparations that contained growth promoting antibiotics. Canadian requirements for registration of these supple-

ments were brought into effect in January, 1951.

The effects of antibiotics, other than to stimulate rate of growth, have not been definitely established. In some instances, increased feed efficiency and a "protein-sparing" effect have been reported. It has also been observed that there appeared to be an increase in the fatness of hogs fed an antibiotic supplement.

In view of the lack of information on the use of antibiotic supplements in typical western Canadian swine rations, it seemed desirable to carry out studies to assess the value of such supplements in rations of growing and finishing pigs. Consequently, a series of experiments was initiated at the University of Alberta in 1949 to study the effect of feeding antibiotics to growing and finishing pigs. This thesis is a summary of the results of these studies since 1951.

REVIEW OF LITERATURE

Antibiotic feed supplements, as they are known today, are developments of commercial animal protein factor supplements that were being used by the feed industry through 1949 and early 1950. The residual products, resulting from fermentations to produce antibiotics, were found to contain vitamin B₁₂ or cyanocobalamin, and were fed to supply this vitamin. However, responses from various sources of supplements containing vitamin B₁₂ differed, and some antibiotic fermentation residues gave a growth response above that attributable to their vitamin B₁₂ content (Stokstad et al., '49). At first this additional growth was thought to result from another member of the "animal protein factor" complex, but the real explanation was found to be the presence of residual primary and secondary antibiotics (Jukes et al., '50).

The growth promoting effect of antibiotics was observed some four years before the announcement of a similar effect of antibiotic residues. In an effort to sterilize the intestinal tract of chicks for vitamin studies, Moore et al. ('46) fed $\frac{1}{4}$ to 1 lb. of streptomycin per ton of ration. While the method did not provide the tool they sought, they did observe that the streptomycin significantly increased the growth of their chicks. However, the high cost of supplementing a ration with pure antibiotics prevented the immediate commercial application of the observation.

The work of Moore was used as a guide for interpretation of results of experiments studying the animal protein factor. The fermentation residues were found to contain small quantities of antibiotics which have since been found to promote growth in poultry, swine, rats

dogs, calves and a number of other species.

A variety of antibiotics have been tested at various levels. Antibiotics have caused a variable response in different classes of livestock and results appear to vary with differences in ration and environment (Cunha et al., '51).

Poultry was one of the first classes of livestock with which the growth promoting effect of antibiotics was demonstrated. Numerous trials with antibiotic supplements have been conducted with poultry since 1949, and the following short review is only an indication of the general results obtained. Brown ('52) in a thesis from the Department of Animal Science summarized the literature on results obtained when poultry were fed antibiotics.

The addition of 0.25 percent aureomycin fermentation mash to either a corn, soybean oil meal, herring meal basal ration, or one in which wheat replaced corn, increased the growth rate of chicks significantly (Berg et al., '50a). On removal of aureomycin supplement from the ration, Berg et al. ('50b) found that there was no carry-over effect from the antibiotic. These results would tend to indicate that the mode of action of the antibiotic in promoting growth is dependent upon the material being present in the diet continuously.

Matterson and Singsen ('51) compared five antibiotics using either an all plant protein basal ration or a ration containing fish meal to replace the soybean oil meal of the all plant ration. Penicillin and bacitracin maintained increased growth rate for the longest period, while streptomycin was least effective in promoting growth. While the greatest percentage increase in growth rate was obtained by supplementing the all plant protein ration, the chicks receiving antibiotic

supplement in the fish meal supplemented ration attained the heaviest final weights.

Turkey poult fed a practical diet were stimulated in growth rate by the addition of aureomycin, streptomycin, terramycin or penicillin (McGinnis et al. '51). Of the supplements tested, penicillin was the most effective.

Supplementation of hog rations with antibiotics was also a development arising from the use of animal protein factor supplements. The addition of vitamin B₁₂ to a ration was shown to increase the rate of gain of pigs (Carpenter, '50; and Edwards et al., '50). The fact that animal protein factor supplement from fermentation mash residues contained a growth factor other than vitamin B₁₂ was demonstrated by Carpenter ('50); Edwards et al. ('50); and Jukes ('50). The dried mycelium of Streptomyces aureofaciens produced a growth response in pigs when added to diets containing vitamin B₁₂ (Jukes, '50). Early work with APF supplements prior to the realization that the presence of antibiotics was responsible for part of the growth response, has been summarized by Beacom ('51) in a thesis for the M.Sc. degree in the Department of Animal Science.

The first large scale experiment reported with antibiotic supplements for swine was conducted by Cunha, ('50). The antibiotic present in an aureomycin fermentation mash increased the rate of gain by 26 to 135 percent with an average of 100 percent increase in 12 trials. The feed efficiency was increased by 5 to 44 percent with an average of 28 percent in the 12 trials. Pigs receiving the supplement did not scour as did those receiving the basal ration. These increases in gain and efficiency from aureomycin supplement were obtained on a

corn-peanut meal ration and thus tend to be greater than would be obtained on a better quality ration.

That different antibiotic supplements vary in their effect when fed to swine is illustrated by Carpenter ('51a) who compared five antibiotics in a ration for swine. Streptomycin, aureomycin, chloromycetin, terramycin and penicillin all stimulated growth and increased feed efficiency, but to varying degrees. All of the antibiotics tested except chloromycetin controlled diarrhea.

Briggs and Beeson ('51) found that 10 mg. of pure aureomycin or 15 mg. of pure streptomycin per lb. of feed increased the rate of gain significantly when fed to healthy weanling pigs. Feed efficiency was increased about 14 to 16 percent, and gains were more uniform when the ration contained the antibiotic supplement. Carpenter ('50) reported that pigs receiving aureomycin supplement had less diarrhea, were smoother and generally thriftier than pigs receiving no antibiotic. Control of scouring has also been reported in several other instances (Burnside, '50; Carpenter '51a; '51b; Catron, '50; and Cunha, '50).

The greatest response in rate of gain by pigs receiving antibiotic supplement is during the growing period (Bowland et al., '51; Hoefer et al., '52). However, in these trials, an increase in growth rate was obtained by feeding antibiotic supplements during the finishing period up to market weight. Runty pigs generally respond more to antibiotics than normal pigs (Bowland et al., '51; and Beeson, '52). For example, Bowland et al. ('51) found that unthrifty pigs fed an aureomycin supplement gained up to 86 percent faster with 20 percent better feed utilization than the control groups.

Catron et al. ('50) compared the addition of several levels of

crystalline aureomycin hydrochloride to a ration for growing pigs. Five, 10, 20 or 40 mg. of aureomycin hydrochloride per lb. of ration all resulted in significantly higher rates of gain than occurred in pigs receiving the basal ration with no antibiotic.

While 2.5 mg. of streptomycin per lb. of feed stimulated growth of pigs, a further increase in growth rate was attained by supplementation at the 15 mg. level (Briggs and Beeson '52). A combination of 12.5 ✓ of vitamin B₁₂ and 15 mg. of streptomycin per pound of feed improved growth rate and feed efficiency more than single additions of either factor. Penicillin at 1 or 5 mg. per lb. of feed resulted in a growth response, with one level as effective as the other (Luecke et al., '51). In an earlier study at the University of Alberta, Hironaka ('51) compared several levels of antibiotic supplement containing aureomycin or penicillin. A supplement containing aureomycin was added at levels of 0.1, 0.25 and 0.5 percent of the ration while penicillin supplement was added at 0.1 and 0.2 percent levels. While appreciable increases in growth rate were obtained in all cases by antibiotic supplementation of the ration, aureomycin supplement at the 0.5 percent level and penicillin supplement at the 0.1 percent level appeared to give the greatest growth response.

Growth has not been promoted by antibiotic supplements in all cases. Sheffy et al. ('52) found only a slight advantage in streptomycin supplementation of a ration for young pigs. Similar findings were reported by Brown ('52) when penicillin or aureomycin supplements were added to chick rations. Crystalline aureomycin hydrochloride or antibiotic in liquid animal protein factor produced no increase in rate of gain or feed efficiency when fed to healthy pigs (Speer et al., '50).

With a corn-peanut meal ration, penicillin supplement resulted in no increase in rate of gain of pigs, while aureomycin supplement increased the growth rate more than streptomycin which in turn was more favorable than penicillin (Cunha et al., '51). Neomycin, at 10 mg. per lb. of feed was reported to have a deleterious effect on rate of gain (Luecke et al., '51).

Aureomycin in sows' rations for 49 to 90 days prior to parturition had no effect on litter size, or size, livability and growth rate of the suckling pigs (Carpenter, '51b). However, aureomycin in a creep feed increased weaning weights from 25 to 36 pounds. Implantation of a single 1000 unit bacitracin pellet in three to five day old pigs has resulted in an 11.3 percent increase in weight of pigs weaned at 56 days (Noland et al., '52).

Bowlan et al., ('51) have reported that the addition of antibiotics to a plant protein ration increased the average daily gain more than when added to a mixed plant and animal protein ration; thus the supplement tended to equalize the two rations, regardless of protein source.

The amount of protein required in a ration may be decreased by antibiotic supplementation. Protein requirement in a corn-peanut meal ration was decreased by 10 percent (Cunha, '50). Differences in rate of gain were negligible between pigs fed rations containing 18 and 15 percent protein to 100 lb., and 15 and 12 percent protein from 100 lb. to market weight when these rations contained 5 mg. of terramycin per lb. of feed (Hoefer et al., '52). Several levels of protein in the ration for pigs were compared by Catron et al. ('52). Levels of 20, 18, 16 and 14 percent protein were fed from weaning to 75 pounds. Each

level was reduced by 3 percent at an average weight of 75 lb. to 17, 15, 13 and 11 percent protein until the pigs reached 150 lb. in weight, when the protein level was reduced an additional 3 percent to 14, 12, 10 and 8 percent respectively. Each level was fed to groups of pigs with and without antibiotic; the antibiotic being aureomycin hydrochloride added at the rate of 10 mg. per lb. of ration. Without antibiotic supplement, a combination of 16, 13 and 10 percent protein for the three periods appeared to supply the pigs' needs; while with an antibiotic supplement, a combination of 14, 11 and 8 percent protein gave results equal to those obtained with higher levels of protein. Thus, the antibiotic appeared to exert a protein sparing effect. On the basis of 24 representative carcasses, the various levels of protein or the presence or absence of antibiotic in the diet resulted in no significant differences in respect to backfat depth, length, depth of body or percentage lean (lean cross section measured at the last rib).

In a review article Almquist ('52) summarized work done by several workers studying the effect of antibiotic supplement on protein requirements in rations for chicks and turkeys. From the reports which were reviewed, it was concluded that antibiotics do not, in general, decrease protein or amino acid requirements. In fact, the effect appeared to be in the opposite direction. Higher protein and amino acid levels may be required in association with the improved growth which is favored by the presence of antibiotics in the feed.

Pigs receiving bacitracin have been reported to have a lowered dressing percentage (Terril et al., '52), while pigs receiving penicillin or aureomycin had a higher dressing percentage (Bowland et al., '51) compared to controls receiving no antibiotic. Advanced Registry scores

were lower on carcasses from pigs which received aureomycin or penicillin, although they were not significantly lower (Bowland et al., '51). The principal effect of antibiotic supplementation of the ration appeared to be a reduction in length (Bowland et al., '51) and increased backfat (Beeson, '52; and Bowland et al., '51). Terril et al. ('52) found no significant difference in thickness of backfat when bacitracin was fed to 100 lb. in weight only, but an average increase of 0.3 cm. in backfat when the supplement was fed until the pigs were marketed.

Vitamin storage in the livers of animals receiving antibiotics has been studied to a limited extent. The concentration of several water soluble vitamins in the livers of chicks receiving antibiotics were quite variable (Monson et al., '52). In this experiment, there was no correlation between growth rate and storage of water soluble vitamins. Brown ('52) found the antibiotics added to a chick ration did not affect riboflavin storage in the liver. Burgess et al. ('51) observed in chicks that vitamin A per gm. of fresh liver and total serum carotenoids were significantly elevated by administration of dietary penicillin. These increases were independent of feed consumption and of body weight response to the antibiotic. The same group of workers have made similar observations with rats, but the data are unpublished.

Other species than the pig, chicken and turkey have responded in varying degrees to antibiotic supplementation of the ration. The growth of rats has been stimulated by feeding an antibiotic (Cravioto-Munoz et al., '51; Sauberlich, '52; and Stern and McGinnis, '50). Weanling rats fed a purified diet with aureomycin supplement grew faster than without supplement, and as rapidly as or faster than with just vitamin B₁₂ (Cravioto-Munoz et al., '51). Stern and McGinnis ('50) using a semi-

purified diet, found that terramycin, streptomycin or aureomycin stimulated the growth of rats beyond that obtained by vitamin B₁₂ supplement alone. Rats fed on a diet deficient in certain of the B-vitamins grew slowly, but with the addition of penicillin or aureomycin, a marked growth stimulation was obtained.

Outside of controlling scouring of calves, antibiotic supplementation of the ration of ruminants has not produced advantageous results. In fact a definite disadvantage was found when aureomycin hydrochloride was fed to steers (Bell et al., '51). Digestibility of crude fiber was reduced and digestive disturbances were produced when 0.2 or 0.6 gm. of aureomycin hydrochloride were fed daily. At the University of Alberta, steers fed aureomycin supplement at a level of 0.25 percent of the grain ration (McElroy and Berg, '51) gained slightly slower than control animals receiving no antibiotic. Antibiotic supplemented steers ate as much grain as the control group, but their appetite for hay was reduced, and they ate 2.5 lb. less per day. Several steers from the antibiotic supplemented lot suffered from moderate to severe diarrhea and went off feed for short periods.

The mode of action of antibiotics is not known, but several theories have been advanced as to how they act. These include; (a) inhibition of toxin producing organisms, (b) reduction in intestinal bacteria and thereby lowered competition between host and microflora for nutrients, (c) selective inhibition permitting increased growth of microorganisms that synthesize unidentified essential nutrients, (d) action of the antibiotic molecule or a fragment of the molecule as a metabolite within the body, (e) reduction in subclinical disease, (f) increased water intake and resulting nutrient absorption, (g) or combinations of

two or more of the foregoing (Elam et al., '51b; Sauberlich, '52; Sieburth et al., '51; and Weber et al., '52).

Moore et al. ('46) noted in their attempt to sterilize the intestinal tract of chicks, that there was a marked reduction in the coliform bacteria of the cecal contents. However antibiotics added to the ration do not give consistent changes in bacterial numbers for most types of bacteria, and the changes in numbers have no correlation with increased growth (Sieburth et al., '51). Clostridium perfringens, an anaerobic bacterium, was inhibited by penicillin or terramycin in turkey poult's and by terramycin in pigs; therefore a possible means of growth promotion may have been prevention of enterotoxemia. Streptothricin and streptomycin produced a very rapid and pronounced reduction in the numbers of both the coliform and non-lactose fermenting organisms found in the feces of mice (Smith and Robinson, '45). Reduced numbers of the organisms were maintained by streptomycin as long as therapy was continued, and no symptoms of vitamin deficiency were observed. Feeding penicillin to the chick increased the numbers of penicillin resistant organisms in the intestinal tract (Elam et al., '51a, '51b). An increase in the yeast count was also reported. Autoclaved penicillin fed to chicks, or bacitracin administered orally or parenterally, had little effect on the fecal microflora, but rates of gain were still increased. Edwards et al., ('51) treated an aureomycin mash with sodium hydroxide to destroy the vitamin B₁₂ and 97 percent of the inhibitory effect of the antibiotic against various organisms. Addition of the treated mash to a corn-peanut meal pig ration resulted in a marked growth response. This would tend to indicate that the mode of action of antibiotics is by some mechanism other than a change in the intestinal microflora.

Injections of antibiotics generally do not produce a growth response. Chicks injected with aureomycin, streptomycin or penicillin showed no significant increase in rate of growth over the control groups (McGinnis et al., '50; and Whitehill et al., '50). However, Elan et al. ('51b) reported that penicillin or autoclaved penicillin injected into a chick stimulated growth. Since parenterally administered antibiotic was found to stimulate growth in some instances, it might be surmised that the antibiotic molecule, or a fragment of it, acts as a metabolite within the body.

Some evidence that antibiotics do not exert an effect on growth through a change in the microflora has been discussed. Combinations of aureomycin, streptomycin, terramycin and penicillin produced no greater response than penicillin alone (McGinnis et al., '51). These are all antibacterial in action, but act on a different range of organisms. Weber et al. ('52) found that rimodycin, which is essentially antifungal in action, promoted growth. When mixed with terramycin, growth was not stimulated any more than when each was fed singly. These results further strengthen the case that antibiotics do not exert their effect through a change in microflora.

The most recent explanation of the increased growth rate was proposed by Weber et al. ('52). They found that the water consumption of chicks was about double in the antibiotic supplemented as compared to the control group. They also reviewed similar observations made by Card ('51) when pigs were fed antibiotic supplements. The increased rate of water consumption may reflect some physiological changes in the animal body. It is postulated that antibiotics increase intestinal protein inhibition, and that the proteins of the intestinal wall take up increasing amounts

of water from the intestinal tract. This would result in increased nutrient absorption.

On the basis of present knowledge, a reasonable explanation of the way antibiotics stimulate growth may incorporate three of the theories proposed. The antibiotic molecule or a fragment of it acting as a metabolite, may cause the necessary physiological changes for increased water and other nutrient absorption. This, coupled with a possible lower general disease level, could stimulate growth.

A comparison of results indicates that the effects of antibiotic supplements will vary with several factors including environment and the ration employed. This would indicate the necessity for measuring the effect under conditions such as prevail in Alberta.

EXPERIMENTAL

A series of experiments was designed to study antibiotic supplementation of swine rations typical of those fed in western Canada.

The following aspects of the use of antibiotic supplements were investigated:

- I The effect of deleting antibiotics from the ration at various stages of the pigs' growth.
- II The effect of antibiotic supplements with various levels of protein during the growing period.
- III The rate of gain and feed efficiency of swine receiving various antibiotic supplements singly and in combination as well as in series.

Analytical studies related to blood lipids and vitamin A storage were carried out in conjunction with some of the above trials.

General Experimental Procedures

All of the pigs used in these experiments were purebred Yorkshire weanling pigs. Allotment was as uniform as possible on the basis of weight, ancestry and sex. The pigs were treated with sodium fluoride to remove round worms, Ascaris lumbricoides var. suis, prior to going on experiment.

The rations used were self-fed and water was available at all times. The antibiotic supplements used were as follows:

Penicillin supplement - Merck's vitamin B₁₂ and antibiotic feed supplement (APF-8), containing 12.5 mg. vitamin B₁₂ and

2 gm. procaine penicillin per pound.

Aureomycin supplement - Lederle's vitamin B₁₂ and antibiotic feed supplement (Aurofac) containing 1.8 mg. vitamin B₁₂ and 1.8 gm. of aureomycin hydrochloride per pound.

Bacitracin supplement - Commercial Solvents Corporation's Baci-ferm-5, containing the equivalent of not less than 5 gm. of bacitracin per pound.

Penbac supplement - Commercial Solvents Corporation's Penbac antibiotic feed supplement containing the equivalent of not less than 5 gm. of bacitracin and 1 gm. of L-Ephen-amine penicillin G, equivalent to 0.635 gm. of crystalline penicillin G per pound.

Feeding oil was fed during the growing period to supply each pig with approximately 7000 I.U. of vitamin A and 1200 I.U. of vitamin D per day.

Each pig was weighed individually at one or two week intervals.

Records of feed consumption were kept to coincide with each time the pigs were weighed, and feed efficiency for each period calculated.

EXPERIMENT I - The effect of deleting antibiotics from the ration at various stages of the pigs' growth.

Earlier work at the University of Alberta has indicated that the greatest growth response from antibiotic supplements is obtained during the growing period, but rate of gain is enhanced during the finishing period. Pigs scored by Canadian Advanced Registry standards have been found to have lower carcass scores when an antibiotic was fed through the entire finishing period.

Experimental Procedure

Forty-two pigs averaging 40 lb. in weight were divided evenly into seven lots of six pigs each. Two basal rations as shown in table 1 were fed. Basal ration 1 was fed until the average weight per pig in a lot reached approximately 125 pounds. From 125 lb. until a market weight of approximately 200 lb., the pigs received basal ration 2.

The individual lots were fed the rations and supplements as given in table 2. In addition all pigs received vitamin A and D supplement until an average weight of 125 lb. was reached.

Table 1

Basal Rations - Experiment I

Period	Constituent		Protein***		Protein/100 lb. ration	
	%	%	1	2	1	2
Barley	63.0	58.0	11.2	14.6	7.07	8.46
Oats	25.0	36.0	11.1	11.1	2.76	3.98
Soybean oil meal	6.0	3.0	46.4	46.4	2.78	1.39
Linseed oil meal	3.0	1.5	31.8	34.4	0.95	0.48
Alfalfa meal	1.8	0.9	17.1	17.4	0.31	0.16
Limestone	0.6	0.3	-	-	-	-
Salt (iodized)	0.6	0.3	-	-	-	-
Total	100.0	100.0			13.9	14.5

*Period 1 was from 40 to 125 lb. average weight.

**Period 2 was from 125 to 200 lb. average weight.

***Based on nitrogen analysis by the Kjeldahl method. The factor 6.25 was used to convert nitrogen to crude protein.

Table 2
Groups and Rations - Experiment I

Lot no.	<u>40 to 75 lb.</u>	<u>Period 1</u>	<u>Period 2</u>
		<u>75 to 125 lb.</u>	<u>125 to 200 lb.</u>
1	Basal 1	Basal 1	Basal 2
2	Basal 1 + 0.5% aureomycin supp.	Basal 1	Basal 2
3	Basal 1 + 0.5% aureomycin supp.	Basal 1 + 0.5% aureomycin supp.	Basal 2
4	Basal 1 + 0.5% aureomycin supp.	Basal 1 + 0.5% aureomycin supp.	Basal 2 + 0.5% aureomycin supp.
5	Basal 1 + 0.05% penicillin supp.	Basal 1	Basal 2
6	Basal 1 + 0.05% penicillin supp.	Basal 1 + 0.05% penicillin supp.	Basal 2
7	Basal 1 + 0.05% penicillin supp.	Basal 1 + 0.05% penicillin supp.	Basal 2 + 0.05% penicillin supp.

The pigs were marketed at as near to 200 pounds as possible.

The carcasses were graded by Canadian Government grades, and cut and scored by Advanced Registry standards.

Livers were collected from a limited number of pigs. Samples of the liver tissue were analyzed to determine vitamin A and carotene storage. These few liver samples were used to evaluate a satisfactory method for determining liver storage of vitamin A so that the method could be used routinely in later trials.

Results and Discussion

A summary of rates of gain and feed efficiencies up to average weights of 75, 125 and 200 lb. is presented in table 3. One pig in lot 1

receiving no antibiotic supplement died after being on the experimental ration for 6 weeks. The pig was not considered in any part of the experiment except in the initial period up to 75 lb. in weight.

Table 3

Rates of Gain and Feed Efficiencies - Experiment I

Ration	Basal	Aureomycin supp. to			Penicillin supp. to		
		75 lb.	125 lb.	200 lb.	75 lb.	125 lb.	200 lb.
Lot no.	1	2	3	4	5	6	7
<u>Initial to 75 pounds</u>							
No. of pigs	6	6	6	6	6	6	6
No. days on trial	35	28	28	28	35	28	28
Av. daily gain lb.	1.08	1.20	1.32	1.35	0.96	1.08	1.14
Av. daily feed lb.	3.64	3.75	3.81	3.94	3.26	3.40	3.48
Feed/100 lb. gain lb.	342	312	290	293	341	313	306
<u>Initial to 125 pounds</u>							
No. of pigs	5	6	6	6	6	6	6
No. days on trial	77	70	63	56	77	77	63
Av. daily gain lb.	1.22	1.23	1.43	1.46	1.17	1.23	1.41
Av. daily feed lb.	4.24	4.37	4.86	4.74	4.12	4.29	4.39
Feed/100 lb. gain lb.	354	357	340	325	353	350	311
<u>Summary - Initial to 200 pounds</u>							
No. of pigs	5	6	6	6	6	6	6
Av. no. days on trial	123	120	109	104	125	126	117
Av. daily gain lb.	1.31	1.34	1.48	1.55	1.28	1.28	1.41
Av. daily feed lb.	4.96	5.13	5.56	5.79	4.88	4.96	5.34
Feed/100 lb. gain lb.	381	383	376	373	380	387	379

Rates of gain were compared by analyses of variance as presented in table 4. Method of Johnson ('50) was used in this and all subsequent statistical analyses.

Table 4

Analyses of Variance of Rates of Gain - Experiment I

Source of Variation	To 75 lb.			To 125 lb.			To 200 lb.	
	D.F.	M.S.	L.S.D. .05	D.F.	M.S.	M.S.		
Treatments	6	0.113*	0.25	6	0.091		0.065	
Error	35	0.044		34	0.047		0.029	

Under the conditions of the trial, up to 75 lb. in weight only lot 4 receiving aureomycin supplement gained at a significantly faster rate than the control group ($p = .05$). During this period, pigs fed aureomycin supplement gained at a faster rate than pigs fed penicillin supplement. At an average weight of 125 lb., the pigs which had been fed aureomycin to 75 lb. had an average gain similar to the control group. Lot 7 receiving penicillin supplement gained at a rate equal to the pigs which had received aureomycin supplement. The differences in rate of gain in the overall period approached significance at the 5 percent level. Pigs fed aureomycin supplement to 125 or 200 lb. appeared to gain at a faster rate than pigs fed penicillin to 125 lb. or 200 lb.

Analyses of variance of rates of gain were calculated combining lots receiving each antibiotic to 75 lb. and to 125 lb.; i.e., lots were combined for statistical analyses as follows:

To 75 pounds; lots 2, 3 and 4 and lots 5, 6 and 7.

To 125 pounds; lots 3 and 4 and lots 6 and 7.

The analyses of variance are presented in table 5.

Table 5

Analyses of Variance - Combining Lots - Experiment I

Source of Variation	Combined to 75 lb.			Combined to 125 lb.		
	D.F.	M.S.	L.S.D. .05 .01	D.F.	M.S.	
Treatments	2	0.260**	0.18 0.24	4	0.11	
Error	39	0.045		36	0.047	

In the period to an average weight of 75 lb., pigs receiving aureomycin supplement gained at a highly significantly ($p = .01$) faster rate than those receiving no antibiotic or penicillin supplement. However, in the period up to 125 lb., no significant differences existed. Although the supplements used contained vitamin B_{12} , earlier work at the University of Alberta (Beacom, '51) showed that vitamin B_{12} had little effect on rate of gain or carcass quality, so that any effects of the supplements are attributed to the antibiotic that they contained.

The results shown on table 3 indicate that the greatest growth stimulation occurred in the growing period. This is in agreement with the findings of Bowland *et al.* ('51) and Hoefer *et al.* ('52). Aureomycin supplement was more effective than penicillin in promoting rate of weight increase. However the levels of the antibiotic supplements fed may have influenced the results. Rates of supplementation of the ration were 0.5 percent aureomycin and 0.05 percent penicillin supplement, which supplied 9 mg. of aureomycin hydrochloride and 1 mg. of procaine penicillin per lb. of feed respectively. An earlier study at the University of Alberta (Hironaka, '51) indicated that aureomycin

supplement fed at the rate of 0.5 percent gave better response than lower levels and that 0.1 percent penicillin gave as great growth stimulation as 0.2 percent.

Removal of the antibiotic from the diet when an average weight of 75 lb. was attained did not appear to cause any marked depression in rate of gain. However, when the antibiotics were fed to 125 lb. in weight, and then removed from the ration, there was a period up to a week when rate of gain was sharply reduced. Following this period, the pigs continued to gain weight at a normal rate. Bird ('50) found that chicks fed streptomycin at the rate of 20 mg. per kg. of feed for 5 weeks, after which the antibiotic was removed from the ration, showed no change in rate of gain. However, when 40 mg. streptomycin per kg. of feed was fed for 5 weeks and then removed from the diet, there was a sharp decrease in rate of gain. Deletion of bacitracin in a swine ration when the pigs reached a weight of 100 lb., resulted in a cessation of accelerated rate of gain (Terril et al., '52). Similar findings were reported by Whitlock ('52) using aureomycin, terramycin and penicillin in swine rations.

Feed efficiency of lots receiving aureomycin supplement to 75 lb. was improved an average of 12.8 percent, while lots receiving penicillin supplement to 75 lb. averaged 6.4 percent improvement. The feed efficiency of pigs fed antibiotics to 125 lb. was improved by 6.2 and 7.0 percent respectively. The pigs fed antibiotics to 75 lbs. had a feed efficiency almost identical to the control lot when an average of 125 lb. was reached. The feed consumed per 100 lb. of gain in the overall period was almost identical from one lot to another. This is in agreement with the findings of Berg et al. ('50), Blight et al. ('52) and Catron et al. ('50), but is not in agreement with reports of several workers who found that feed

efficiency was improved by feeding antibiotics to swine (Bowland *et al.*, '51; Briggs and Beeson, '51; Carpenter, '51a; and Cunha, '50).

Average carcass measurements and Advanced Registry scores are presented in table 6. No statistical differences were found in length of side, shoulder fat, loin fat, backfat score or total score. However, a trend toward a reduction in Government grade, belly grade, length of side, area of loin and total A.R. score was evident when the antibiotics were fed to market weight. The reduction in total score from 73 to 61 resulted from lower score in length, belly and loin. Feeding of the antibiotic supplements to 75 or 125 lb. did not affect carcass grades or A.R. measurements.

Table 6

Carcass Measurements, Scores and Grades - Experiment I

Ration	Control	Aureomycin supp. to			Penicillin supp. to			
		75 lb.	125 lb.	200 lb.	75 lb.	125 lb.	200 lb.	
Lot no.		1	2	3	4	5	6	7
Grade	A	3	2	2	0	3	3	1
	B ₁	2	4	3	6	3	3	5
	C	0	0	1	0	0	0	0
Carcass wt.								
Hot	lb.	154.2	154.8	155.5	156.5	153.8	153.8	156.5
Cold	lb.	150.4	149.7	150.0	152.8	149.0	148.8	152.0
Shrinkage	%	2.53	3.41	3.67	3.73	3.22	3.36	2.96
Length of side,	in.	30.9	30.8	31.0	30.6	30.7	30.9	30.3
Thickness of fat								
Shoulder	in.	1.94	2.10	2.00	2.08	1.98	1.93	2.03
Back	in.	1.08	1.10	1.08	1.10	1.05	1.03	1.12
Loin	in.	1.46	1.53	1.50	1.48	1.42	1.40	1.47
Area of loin	sq. in.	3.55	3.54	3.49	3.23	3.48	3.59	3.50
Advanced Registry scores								
Length	(20)	16.6	16.7	16.0	13.8	15.7	17.7	11.0
Backfat	(20)	10.0	7.0	8.8	9.5	9.0	9.0	9.8
Balance	(10)	6.6	7.3	7.0	6.2	6.5	6.7	6.5
Belly	(20)	15.0	13.7	14.7	12.3	16.3	17.0	14.3
Loin	(20)	14.8	14.0	13.0	9.3	12.7	15.7	12.7
Type	(10)	10.0	10.0	10.0	10.0	10.0	10.0	10.0
Total	(100)	73	69	70	61	70	76	64

Dressing percentages averaged very close to 75 percent in all lots, and the addition of an antibiotic supplement had no appreciable effect on this percentage. Earlier work in the Department of Animal Science has indicated a trend toward an increased dressing percent when antibiotics are fed in the finishing period (Bowland et al., '51), while other workers have reported a decreased dressing percent from antibiotic supplementation of the ration for swine (Terril et al., '52).

Carcasses of pigs which received an antibiotic shrank an average of 5.1 lb. on cooling for approximately 48 hours, while the carcasses of pigs which did not receive any antibiotic shrank an average of 3.8 pounds. This significant difference ($p = .05$) in shrinkage indicates that the carcasses from antibiotic fed pigs probably contained more water. This may be explained on the basis of the observations made by Card ('51) and Weber et al. ('52) that pigs and chicks fed antibiotics drank more water than animals receiving no antibiotic supplement.

The results of the analyses of liver tissue for vitamin A and carotene did not indicate any trend toward increased vitamin A storage when antibiotic supplements were fed. The limited data obtained in this experiment are summarized in table 7. The analyses in this and subsequent trials, were made by the method described by Berl and Peterson ('43) using livers which had been stored in a frozen state.

Table 7

Vitamin A Concentration in the Liver - Experiment I

Ration	Control	Aureomycin to 200 lb.	Penicillin to 200 lb.
Lot no.	1	4	7
No. of livers	2	1	2
Av. vitamin A $\sqrt{\text{gm.}}$	12.78	12.20	7.86
Av. carotene $\sqrt{\text{gm.}}$	12.50	2.77	8.96

Summary - Experiment I

1. Antibiotic supplementation of a ration for pigs tended to cause increased rate of gain, although generally not to a statistically significant extent.
2. Antibiotic supplements produced their greatest response in rate of gain in a period from weaning to an average weight of 75 pounds.
3. Aureomycin supplement resulted in significant differences in rate of gain over penicillin supplement.
4. When an antibiotic was included in the ration until the pigs were marketed, a lowering in carcass quality as compared to pigs receiving no antibiotic was indicated, although differences were not significant. The supplementation of a ration with antibiotics, until the pigs reached average weights of 75 or 125 lb., did not appear to affect carcass quality.
5. Greater shrinkage in weight during cooling occurred in the carcasses from the pigs which had been fed an antibiotic supplement.

6. No difference in liver storage of vitamin A and carotene appeared to result from feeding antibiotic supplements.

EXPERIMENT II - The effect of antibiotic supplements with various levels of protein during the growing period.

Trial A

A "protein-sparing" effect has been reported when antibiotic supplements are added to rations for swine, but such studies have not been conducted using Canadian type rations. The effect on carcass quality of the addition of antibiotic supplements to rations varying in protein level has not been studied.

Experimental Procedure

Thirty-six pigs averaging 33.5 lb. were divided into six lots of six pigs each. The rations for all lots contained the same ratio of grain (2 barley: 1 oats) and the amount of protein supplement was varied to obtain the percentage protein desired for each lot. The crude protein content of the grains as well as of the ingredients of the protein supplement were determined by calculation following nitrogen determination by the Kjeldahl method. The barley used in this trial had 11.4 percent and the oats 12.3 percent crude protein. The constituents of the protein supplement with the amount of each and percent crude protein are presented in table 8.

Table 8
Protein Supplement - Trial A

	<u>Constituent</u> %	<u>Protein</u> %	<u>Protein/100 lb. supp.</u> <u>lb.</u>
Meat scraps	35	56.7	19.83
Soybean oil meal	25	44.0	10.99
Linseed oil meal	25	34.3	8.57
Alfalfa meal (dehydrated)	<u>15</u>	<u>16.7</u>	<u>2.50</u>
Total	100		41.9

The lots and rations up to approximately 110 lb. in weight were as given in table 9. The antibiotic supplement contained penicillin and supplied 2 mg. of procaine penicillin per lb. of feed. The mineral mixture was made up of equal parts limestone and iodized salt.

Table 9
Lots and Rations - Trial A

Lot no.	Crude protein %	Antibiotic	Total grain %	Barley %	Oats %	Protein supp. %	Mineral %
1	17	none	81.0	54.0	27.0	18.0	1.0
2	17	0.1%	81.0	54.0	27.0	18.0	1.0
3	15	none	87.7	58.5	29.2	11.3	1.0
4	15	0.1%	87.7	58.5	29.2	11.3	1.0
5	13	none	94.3	62.9	31.4	4.7	1.0
6	13	0.1%	94.3	62.9	31.4	4.7	1.0

As the pigs of each lot reached an average weight of 110 lb., they were changed to a ration containing 13 percent protein and no antibiotic, the same as lot 5 received during the growing period.

Results and Discussion

A summary of the rates of gain and feed efficiencies is presented in table 10. Analyses of variance, as presented in table 11 were carried out on rates of gain. Six weeks after initiation of the trial, a pig in lot 2, receiving 17 percent protein with antibiotic, became ill and was removed from the experiment and a replacement was put in the lot. Since the pig which was substituted in lot 2 received the antibiotic for only 3 weeks, and the gain by this pig appeared out of line with others in the lot, it was not included in the summary of the data.

Table 10

Rates of Gain and Feed Efficiencies - Trial A

Ration	<u>17% protein</u>	<u>15% protein</u>	<u>13% protein</u>			
Antibiotic (penicillin)	-	+	-	+	-	+
Lot no.	1	2	3	4	5	6
No. of pigs	6	5	6	6	6	6
<u>Initial to 75 lb.</u>						
No. days on trial	42	42	49	42	56	42
Av. daily gain	lb.	0.95	1.10	0.78	0.98	0.76
Av. daily feed	lb.	3.07	2.87	3.03	2.83	3.12
Feed/100 lb. gain	lb.	322	299	386	289	409
<u>Initial to 110 lb.</u>						
No. days on trial	70	70	73	70	84	70
Av. daily gain	lb.	1.11	1.23	1.00	1.19	0.89
Av. daily feed	lb.	3.83	3.80	3.85	3.78	3.87
Feed/100 lb. gain	lb.	346	329	385	316	433
<u>Summary - Initial to 200 lb.</u>						
Av. no. days on trial	139	125	146	128	154	135
Av. daily gain	lb.	1.20	1.41	1.15	1.31	1.10
Av. daily feed	lb.	5.06	5.33	5.33	5.16	5.17
Feed/100 lb. gain	lb.	422	397	465	393	472

Table 11

Analyses of Variance of Rates of Gain - Trial A

Period		Initial to 75 lb.	Initial to 110 lb.	Initial to 200 lb.	75 to 110 lb.	110 to 200 lb.
Source of variation	D.F.	M.S.	M.S.	M.S.	M.S.	M.S.
Antibiotic	1	0.252*	0.289**	0.248**	0.217*	0.226*
Protein	2	0.088	0.067	0.012	0.091	0.023
Interaction	2	0.011	0.015	0.008	0.025	0.038
Error	29	0.034	0.028	0.019	0.033	0.043

As indicated in table 11, significant or highly significant differences in rate of gain were produced by feeding a penicillin supplement to swine. Differences in rate of gain due to different protein levels were not significant. However, a trend toward slower rate of gain appeared as the level of protein was decreased, particularly in lots not receiving an antibiotic supplement. Hoefer *et al.* ('52) reported similar findings when terramycin was supplemented to swine rations containing 15 and 18 percent protein. The interaction between the different levels of protein and antibiotic had no affect on rate of weight increase.

Differences in rate of gain due to antibiotic supplement in the 3 periods of growth (initial to 75 lb., 75 to 110 lb., with antibiotic; and 110 to 200 lb. without antibiotic) were all significant ($p = .05$). The rate of gain continued to be enhanced, particularly in lot 2 receiving 17 percent protein and antibiotic, following removal of the antibiotic from the ration. This is not in agreement with the findings in earlier work reported in Experiment I or Terril *et al.* ('52), where it was found that when an antibiotic was removed from the ration, there was a cessation in

accelerated rate of gain. No marked depression in rate of gain for a short period following removal of the antibiotic from the ration was evident, as was the case in the previous experiment (Experiment I) when the antibiotics were removed at 125 lb. in weight.

A small increase in feed efficiency was observed when antibiotic supplements were added to the ration. The feed efficiency appeared to be reduced as the level of protein was lowered in the period up to 110 lb. in weight.

Government grades and Advanced Registry measurements and scores are presented in table 12.

Table 12

Carcass Grades, Measurements and Scores - Trial A

Ration	17% protein		15% protein		13% protein	
Antibiotic	-	+	-	+	-	+
Lot no.	1	2	3	4	5	6
Grade	A B ₁	5 1	2 4	5 1	3 3	2 4
Carcass wt.						
Hot	lb.	153.0	152.2	154.5	156.0	157.7
Cold	lb.	148.3	147.0	149.7	149.3	153.0
Shrinkage	%	3.17	3.54	3.21	4.14	3.07
Length of side	in.	31.2	30.8	31.1	30.5	30.7
Thickness of fat						
Shoulder	in.	1.92	2.00	1.85	1.98	2.08
Back	in.	0.90	1.05	0.92	1.00	1.02
Loin	in.	1.32	1.48	1.33	1.43	1.50
Area of loin	sq. in.	3.48	3.17	3.48	3.20	3.17
Advanced Registry scores						
Length	(20)	17.7	16.2	19.5	15.3	15.8
Backfat	(20)	13.8	7.5	14.0	11.8	8.2
Balance	(10)	5.8	5.5	6.3	6.0	5.8
Belly	(20)	16.7	15.0	16.7	16.0	15.3
Loin	(20)	13.7	9.7	14.3	10.3	14.3
Type	(10)	10.0	10.0	10.0	10.0	10.0
Total	(100)	78	64	81	70	70
						66

Analyses of variance were carried out on carcass measurements, and on belly and backfat score. A summary of the analyses is presented in table 13.

Table 13

Analyses of Variance of Carcass Measurements, Scores and Shrinkage - Trial A

Source of variation	D.F.	Fat				Area of loin	Score			Shrinkage
		Length	Shoulder	Loin	Back		Belly	Backfat		
Antibiotic	1	0.280	0.028	0.111*	0.062*	1.096**	18.777	40.11	6.680*	
Protein	2	0.110	0.063	0.024	0.015	0.018	13.000	41.028	0.895	
Interaction	2	1.075	0.027	0.008	0.014	0.026	1.445	54.195	0.930	
Error	30	0.328	0.024	0.023	0.012	0.133	19.578	25.028	1.212	

Total Advanced Registry score of carcasses from pigs fed antibiotic compared to pigs not fed antibiotic was reduced by 12.5 percent. Carcasses of pigs fed antibiotic were significantly ($p = .05$) thicker in loin fat and backfat and highly significantly ($p = .01$) lower in area of loin. This is not in agreement with Experiment I reported earlier, or with the findings of Catron *et al.* ('52), where it was found that when the antibiotic was removed prior to 125 lb. in weight, there was no effect on carcass fat measurements. This may be at least partially explained by the carry-over effect of the antibiotic which was shown by the accelerated rate of gain which was observed in lot 2. The length of carcasses of pigs fed 17 and 15 percent protein with antibiotic supplement was decreased in comparison to the carcasses from pigs which were not fed an antibiotic. However, carcasses from pigs fed 13 percent protein with antibiotic were longer

than those from pigs fed no antibiotic. This difference in response to protein level with and without antibiotic approached significance at the five percent level. Protein level alone had no significant effect on carcass quality. The trend toward lower belly scores from lower levels of protein and antibiotic supplementation of the ration was not statistically significant. McNeekan ('40) found that pigs on a high plane of nutrition were fatter and shorter than pigs on a low plane of nutrition, which might be a partial explanation of the results obtained in this experiment.

An average of 0.86 lb. more shrinkage in carcasses from pigs fed antibiotic compared to those receiving no antibiotic was found to be significant ($p = .05$). This is in agreement with findings reported earlier. A possible explanation of this is that there was an increased water consumption by pigs fed antibiotic supplement which resulted in more water in the tissue.

Samples of blood were drawn from all of the pigs after they had been on trial for 9 weeks. The blood was obtained from the anterior vena cava by the method described by Carle and Dewhirst ('42) using potassium oxalate as an anticoagulant. The lipid level of the plasma was determined using the method described by Allen ('38). The blood was drawn and frozen before the plasma was separated. Average plasma lipid levels are presented in table 14.

Table 14

Plasma Lipid Levels - Trial A

Ration	17% protein		15% protein		13% protein	
Antibiotic	-	+	-	+	-	+
Lot no.	1	2	3	4	5	6
Av. plasma lipids mg. %	71.2	82.5	36.5	45.3	81.3	81.2

There appeared to be no definite trend in levels of plasma lipid between pigs fed antibiotic supplement compared to pigs receiving no antibiotic. Statistically significant correlations were found between plasma lipid levels and some carcass measurements and scores.

Correlations were as follows:

Area of loin	-0.698**	(r.01 = 0.424)
Shoulder fat	0.356*	(r.05 = 0.330)
Thickness of loin	0.371*	(r.05 = 0.330)
Backfat score	-0.437**	(r.01 = 0.424)

The correlation between plasma lipid level and thickness of backfat was 0.206, which was not found to be significant. In general, the correlations would indicate that plasma lipid levels were a reasonable measure of the fatness of the carcass.

The livers were collected when the pigs were slaughtered. Samples were analyzed for storage of vitamin A and carotene. Average values for vitamin A activity are presented in table 15.

Table 15

Vitamin A Activity in the Liver - Trial A

Ration	<u>17% protein</u>	<u>15% protein</u>	<u>13% protein</u>		
Antibiotic	-	+	-	+	-
Lot no.	1	2	3	4	5
Vit. A \sqrt{gm} .	7.02	5.61	6.86	6.99	6.07
Carotene \sqrt{gm} .	1.80	2.43	2.42	2.42	2.92

There did not appear to be any effect on vitamin A and carotene storage in the liver from the addition of an antibiotic supplement or from different levels of protein in the rations fed. This is not in agreement with Burgess et al. ('51) who found that liver storage of vitamin A was increased when chicks were fed an antibiotic. The antibiotic was removed from the pigs' rations at 110 lb. in weight so that any effect on vitamin A storage in the liver may have been lost by the time the pigs reached market weight.

Trial B

In trial A, the rate of gain by pigs fed 17, 15 or 13 percent protein with an antibiotic supplement was significantly greater than gains with the same rations without antibiotic supplement, with a trend toward slower gains being observed as the protein level was decreased. This trial indicated that there were significant differences in carcass quality when an antibiotic supplement was fed, even though it was removed at an average weight of 110 pounds. Correlations between plasma lipid levels and certain carcass measurements were found to be significant.

There was no apparent difference in liver storage of vitamin A or carotene from feeding the rations varying in protein level with or without antibiotic. A duplicate trial was conducted to determine the repeatability of the first. Both trials were initiated in the spring of the year.

Experimental Procedure

Thirty pigs averaging 40.3 lb., were divided into six groups of five pigs each. The rations were formulated as in trial A, containing the same ratio of grain (2 barley: 1 oats), and type of protein supplement. On the basis of Kjeldahl nitrogen determination, the barley used in this trial contained 12.6 percent and the oats 11.9 percent crude protein. The composition and crude protein content of the protein supplement are presented in table 16. The lots and rations up to 110 lb. in weight were as presented in table 17. The antibiotic supplement contained penicillin as in trial A. The mineral mixture was made up of equal parts limestone and iodized salt. All other experimental procedures were as described in trial A.

Table 16

Protein Supplement - Trial B

	Constituent %	Protein %	Protein/100 lb. supp. lb.
Meat scraps	35	50.5	17.68
Soybean oil meal	25	43.9	10.98
Linseed oil meal	25	35.2	8.80
Alfalfa meal	<u>15</u>	<u>16.8</u>	<u>2.52</u>
Total	100		40.0

Table 17

Lots and Rations - Trial B

Lot no.	Crude protein %	Antibiotic	Total grain %	Barley %	Oats %	Protein supp. %	Mineral %
1	17	none	81.9	54.6	27.3	17.1	1.0
2	17	0.1%	81.9	54.6	27.3	17.1	1.0
3	15	none	89.1	59.4	29.7	9.9	1.0
4	15	0.1%	89.1	59.4	29.7	9.9	1.0
5	13	none	96.4	64.3	32.1	2.6	1.0
6	13	0.1%	96.4	64.3	32.1	2.6	1.0

Results and Discussion

The average rates of gain and feed efficiencies are presented in table 18. Analyses of variance for rates of gain are presented in table 19.

One pig in lot 4 receiving 15 percent protein with antibiotic grew at an abnormally slow rate. The pig was withdrawn from the experiment when the last of the other pigs of the same lot was marketed. However, this pig was included in calculations for average gains, feed efficiencies and analyses of variance. No information as to carcass quality or vitamin A liver storage was available for this pig.

Table 18

Rates of Gain and Feed Efficiencies - Trial B

Ration	17% protein		15% protein		13% protein	
Antibiotic	-	+	-	+	-	+
Lot no.	1	2	3	4	5	6
No. of pigs	5	5	5	5	5	5
<u>Initial to 110 lb.</u>						
No. days on trial	63	56	70	63	70	63
Av. daily gain	lb.	1.23	1.32	1.07	1.07	0.99
Av. daily feed	lb.	3.82	4.59	4.67	3.98	4.45
Feed/100 lb. gain	lb.	312	348	437	371	452
<u>Summary - Initial to 200 lb.</u>						
No. days on trial	118	106	122	122	120	125
Av. daily gain	lb.	1.39	1.55	1.34	1.20	1.29
Av. daily feed	lb.	5.08	6.00	6.06	4.73	5.24
Feed/100 lb. gain	lb.	365	386	451	395	405

Table 19

Analyses of Variance of Rates of Gain - Trial B

Period	<u>Initial to 110 lb.</u>		<u>Initial to 200 lb.</u>
Source of variation	D.F.	M.S.	M.S.
Antibiotic	1	0.034	< 0.001
Protein	2	0.158	0.125
Interaction	2	0.007	0.065
Error	24	0.113	0.051

No statistically significant differences in rate of gain were found up to 110 lb. in weight even if the one pig which appeared to grow at an abnormally slow rate was excluded from the analysis. These results are not in agreement with the results of trial A, or with other work reported from the University of Alberta (Beacom, '51; Bowland et al., '51; and Hironaka, '51) where the rate of gain was increased by antibiotic supplements. Feed efficiency was not affected by antibiotic supplementation of the ration, but a trend toward lower feed efficiency was found at lower levels of protein in the ration. No protein "sparing effect" was observed when antibiotic supplements were added to the ration. Neither feed efficiency, nor rate of gain varied significantly in pigs fed rations of different protein level. This same observation held true for the over-all growth and finishing period to market weight.

Government grades and Advanced Registry measurements and scores of the carcasses are presented in table 20.

Table 20

Carcass Grades, Measurements and Scores - Trial B

Ration		<u>17% protein</u>		<u>15% protein</u>		<u>13% protein</u>	
Antibiotic		-	+	-	+	-	+
Lot no.		1	2	3	4	5	6
Grade	A	5	4	0	2	2	4
	B ₁	0	1	5	2	3	1
Carcass wt.							
Hot	lb.	154.2	156.0	155.6	156.0	150.6	149.4
Cold	lb.	150.2	151.0	151.0	151.0	147.0	145.4
Shrinkage	%	2.66	3.31	3.05	3.31	2.45	2.75
Length of side	in.	30.8	31.3	31.0	30.9	30.4	30.4
Thickness of fat							
Shoulder	in.	1.86	1.98	2.18	1.98	2.00	1.84
Back	in.	0.96	0.96	1.14	1.08	1.00	0.98
Loin	in.	1.34	1.48	1.58	1.48	1.56	1.40
Area of loin	sq. in.	3.46	3.29	3.50	3.41	3.17	3.19
Advanced Registry scores							
Length	(20)	18.0	19.8	18.0	18.5	15.0	15.8
Backfat	(20)	13.8	8.4	2.8	12.0	4.8	10.2
Balance	(10)	6.8	7.0	6.4	6.3	6.6	6.2
Belly	(20)	17.2	15.2	16.0	15.5	17.2	18.0
Loin	(20)	13.2	11.2	13.2	12.5	10.8	11.2
Type	(10)	10.0	10.0	10.0	10.0	10.0	10.0
Total	(100)	79	72	66	75	64	71

A summary of the analyses of variance for carcass measurements, belly and backfat scores and carcass shrinkage is presented in tables 21 and 21A.

Table 21

Analyses of Variance of Carcass Measurements - Trial B

Source of variation	D.F.	Length		Shoulder		Fat Loin		Back		Area of loin	
		M.S.	L.S.D. .05	M.S.	L.S.D. .05	M.S.	M.S.	L.S.D. .05	M.S.	N.S.	
Antibiotic	1	.152		0.052		0.014	0.008			0.054	
Protein	2	1.328*	0.55	0.089		0.037	0.060*	0.11		0.193	
Interaction	2	0.260		0.071*	0.16	0.062	0.002			0.019	
Error	23	0.349		0.015		0.030	0.015			0.182	

Table 21A

Analyses of Variance of Carcass Scores and Shrinkage - Trial B

Source of variation	D.F.	Score		Shrinkage	
		Belly	Backfat	M.S.	L.S.D. .05
Antibiotic	1	1.916	62.510		2.500
Protein	2	8.809	50.441		2.448
Interaction	2	5.120	135.690*	7.55	0.426
Error	23	7.710	33.320		1.670

Antibiotic supplementation of the ration to 110 lb. did not affect length, shoulder fat, loin fat or area of loin. This is in agreement with earlier results at the University of Alberta (see Experiment I),

and work reported by Terril et al. ('52) who found no significant difference in backfat thickness when bacitracin was fed to 100 pounds. However, it does not agree with the results obtained in trial A. Carcasses from pigs fed 13 percent protein were significantly shorter than carcasses from pigs fed 15 or 17 percent protein. The difference in response to protein levels with and without antibiotic was significant ($p = .05$).

The difference in carcass measurements between trial A and trial B may be a reflection of the difference in rate of gain between the two trials. Antibiotic supplementation of the ration did not affect the rate of gain as markedly in trial B as in trial A. The quality of the carcasses is undoubtedly affected by rate of gain as shown by McMeekan ('40). Since the rate of weight increase was not affected markedly by antibiotic supplementation of the ration in trial B, the difference in carcass measurements in turn may not have been markedly affected by the rate of gain. If this is true, then the effect of antibiotics on carcass quality is not a direct effect, but rather an indirect effect through the rate of gain.

A trend toward greater shrinkage from hot to cold carcass weight of pigs fed antibiotic supplement compared to pigs not fed an antibiotic was found, although differences were not significant. In previous experiments, a similar but larger effect of antibiotic supplements on carcass shrinkage was noted.

Samples of blood were taken from all pigs at the start of the experiment and after 5 and 10 weeks. Blood plasma lipid levels were determined using the method described by Allen ('38). Average lipid levels for each lot for the three dates samples were taken are presented in table 22. Analysis of variance of plasma lipid levels is presented in table 23.

Table 22

Plasma Lipid Levels - Trial B

Ration	<u>17% protein</u>	<u>15% protein</u>	<u>13% protein</u>			
Antibiotic	-	+	-	+	-	+
Lot no.	1	2	3	4	5	6
Lipid - mg. %						
Initial	125	120	153	148	129	142
5 weeks	119	138	148	148	156	173
10 weeks	<u>147</u>	<u>123</u>	<u>138</u>	<u>130</u>	<u>127</u>	<u>151</u>
Average	127	127	146	142	137	156

Table 23

Analysis of Variance of Plasma Lipid Levels - Trial B

Source of variation	D.F.	M.S.	L.S.D. .05
Dates	2	1680.5	
Antibiotic	1	81.7	
Protein	2	2925.6	
D x P	4	952.0	
D x A	2	377.4	
A x P	2	1796.4	
D x A x P	4	2603.9*	36.6
Error	72	837.3	

Plasma lipid level was not affected by the protein level of the ration or by the addition of an antibiotic supplement to the ration. There were no differences in the three dates (initial, 5 and 10 weeks)

when samples of blood were taken. The interaction of any two of protein, antibiotic or date had no effect on plasma lipid levels. A differential response of the three factors produced the significant interaction which was found, but no interpretation can be made of the data.

Correlations between plasma lipid level and backfat score, loin fat, or area of loin were found to be not significant. This is not in agreement with the results of Trial A when significant correlations were found between these measurements and plasma lipid levels.

Samples from the livers were analyzed for storage of vitamin A and carotene. Averages of vitamin A activity are presented in table 24. No definite differences were observed between the vitamin activity of the livers of pigs in the various lots.

Table 24

Vitamin A Activity in the Liver - Trial B

Ration	<u>17%</u> protein	<u>15%</u> protein	<u>13%</u> protein		
Antibiotic	-	+	-	+	-
Lot no.	1	2	3	4	5
Vitamin A $\sqrt{\text{gm.}}$	12.15	7.37	7.29	8.47	5.51
Carotene $\sqrt{\text{gm.}}$	1.75	1.44	1.31	1.25	0.95

Summary - Experiment II

1. Two studies were conducted on penicillin supplementation of hog rations containing 17, 15 and 13 percent protein with and without antibiotic supplement until the pigs reached an average weight of 110 lb. A ration containing 13 percent protein and no antibiotic

- was fed after the pigs reached this weight until they were marketed.
2. The pigs responded differently to the rations in the two trials, with respect to rate of gain and carcass measurements.
 3. The pigs in the first trial gained weight at a significantly faster rate when antibiotic supplement was added to the ration, while there was a trend toward faster gains as the protein level of the ration increased. Protein level appeared to have the same effect in the second trial but antibiotic supplement had little effect on rate of gain.
 4. A trend toward greater feed efficiency was found at the higher levels of protein in both trials, but feed efficiency appeared to be improved by antibiotic supplement in the first trial only.
 5. Shrinkage from hot to cold carcass weight was greater in carcasses from pigs fed an antibiotic supplement in comparison to those receiving no supplement.
 6. Positive correlations between plasma lipid levels and Advanced Registry measurements of thickness of shoulder fat and loin fat were statistically significant ($p = .05$) in the first trial. Area of loin and backfat score were negatively correlated with plasma lipid levels in the first trial ($p = .01$). In the second trial there were no significant correlations between plasma lipid levels and any of the carcass measurements.
 7. The level of vitamin A and carotene storage in the liver did not appear to be affected by antibiotic supplementation of the ration or by the different levels of protein fed.

EXPERIMENT III - The rate of gain and feed efficiency of swine receiving various antibiotic supplements singly and in combination as well as in series.

Several studies have been conducted at the University of Alberta with aureomycin and penicillin supplements, both of which have usually given favorable growth responses. Penicillin supplements have given less consistent increases in rate of gain than aureomycin supplements. There are few data, and none from the University of Alberta, on the complementary effect of different antibiotics fed together or in series.

Experimental Procedure

Forty-four pigs averaging 36.3 lb. in weight were divided into four lots of eight pigs each and two lots of six pigs each. After 5 weeks, the pigs in the lots with eight in each were subdivided into two groups. The pigs for each group were identified at the time of the original allotment. Thus the final allotment was eight lots with four pigs in each and two lots with six pigs in each. The trial was conducted for an additional 5 weeks, making the entire trial of 10 weeks duration.

The basal ration was the same for all lots throughout the entire experiment, as shown in table 25. Also shown in the table is the crude protein content of each constituent and the amount of protein supplied to the ration. Allotment and antibiotic supplements fed are given in table 26.

Table 25

Basal Ration and Protein Content - Experiment III

	Constituent %	Protein %	Protein/100 lb. ration lb.
Barley	63.0	11.3	7.09
Oats	25.0	11.9	2.96
Soybean oil meal	6.0	43.9	2.63
Linseed oil meal	3.0	35.2	1.06
Alfalfa meal	1.8	16.8	0.30
Limestone	0.6	-	-
Salt	<u>0.6</u>	<u>-</u>	<u>-</u>
	100.0		14.0

Table 26

Lots and Rations - Experiment III

Lot no.	Initial to 5 weeks	Lot no.	5 to 10 weeks
1	Basal ration	1	Basal ration
2	Basal + 0.5% aureomycin supp.	2A	Basal + 0.5% aureomycin supp.
		2B	Basal + 0.1% penicillin supp.
3	Basal + 0.1% penicillin supp.	3A	Basal + 0.5% aureomycin supp.
		3B	Basal + 0.1% penicillin supp.
4	Basal + 0.25% bacitracin supp.	4A	Basal + 0.25% bacitracin supp.
		4B	Basal + 0.5% aureomycin supp.
5	Basal + 0.25% penbac supp.	5A	Basal + 0.25% bacitracin supp.
		5B	Basal + 0.25% penbac supp.
6	Basal + 0.05% penicillin supp. + 0.25% aureomycin supp.	6	Basal + 0.05% penicillin supp. + 0.25% aureomycin supp.

Results and Discussion

Average rates of gain and feed efficiencies are presented in table 27.

Table 27

Rates of Gain and Feed Efficiencies - Experiment III

Lot no.	Ration	Days on trial	Av. daily gain lb.	Av. daily feed lb.	Feed/100 lb. gain lb.
<u>Initial to 5 weeks</u>					
1	Basal	35	0.89	3.00	337
2	Aureomycin supp.	35	1.11	3.36	303
3	Penicillin supp.	35	0.90	3.04	360
4	Bacitracin supp.	35	0.80	2.30	287
5	Penbac supp. (peni- cillin and bacitracin)	35	0.83	2.76	335
6	Penicillin and aureomycin supp.	35	1.15	3.66	317
<u>5 to 10 weeks</u>					
1	Basal	35	1.06	4.09	387
2A	Aureomycin	35	1.72	6.03	350
2B	Penicillin	35	1.34	5.59	391
3A	Aureomycin	35	1.71	5.79	337
3B	Penicillin	35	1.44	4.96	314
4A	Bacitracin	35	1.31	4.24	325
4B	Aureomycin	35	1.55	5.39	348
5A	Bacitracin	35	1.14	4.91	342
5B	Penbac	35	1.57	5.11	325
6	Penicillin and aureomycin	35	1.58	5.82	333

Table 27A

Summary of Rates of Gain and Feed Efficiencies - Experiment III

Lot no.	Ration		Days on trial	Av. daily gain lb.
	1st 5 weeks	2nd 5 weeks		
1	Basal	Basal	70	0.97
2A	Aureoencycin	Aureoencycin	70	1.39
2B	Aureomycin	Penicillin	70	1.29
3A	Penicillin	Aureomycin	70	1.29
3B	Penicillin	Penicillin	70	1.14
4A	Bacitracin	Bacitracin	70	0.98
4B	Bacitracin	Aureomycin	70	1.25
5A	Penbac	Bacitracin	70	1.15
5B	Penbac	Penbac	70	1.18
6	Penicillin and aureomycin	Penicillin and aureomycin	70	1.45

Analyses of variance for rate of gain are presented in tables 28 and 28A.

Table 28

Analysis of Variance of Rates of Gain - Experiment III

Initial to 5 weeks

Source of variation	D.F.	M.S.	L.S.D. .05
Treatment	5	0.170*	0.25
Error	38	0.053	

Table 28A

Analyses of Variance of Rates of Gain - Experiment III

Source of variation	D.F.	5 to 10 weeks			Entire trial		
		M.S.	L.S.D. .05	.01	M.S.	L.S.D. .05	.01
Treatments	9	0.202**	0.31	0.42	0.125**	0.27	0.37
Error	34	0.052			0.040		

The groups receiving aureomycin supplement or aureomycin and penicillin supplement gained at a significantly ($p = .05$) faster rate than the control group during the first 5 weeks. Penicillin did not appear to promote rate of gain and bacitracin supplement appeared to retard the rate of weight increase.

In the period from 5 to 10 weeks, the pigs receiving aureomycin supplement, penbac supplement or aureomycin and penicillin jointly gained weight at a highly significantly ($p = .01$) faster rate than the control group. In this period, one group receiving penicillin and another receiving bacitracin gained weight at a significantly ($p = .05$) faster rate than the controls, while two other groups receiving the same supplements did not.

In the over-all period, only the groups receiving aureomycin during the entire trial, either alone or in combination, gained weight at a rate which was highly significantly ($p = .01$) faster than the control group. All antibiotics or combinations of antibiotics except bacitracin tended to promote some increase in rate of gain.

These findings are not in agreement with those reported by Matterson and Singsen ('51) who obtained a growth response from all

three antibiotics, or Bowland et al. ('51) and Carpenter ('51a) who found that aureomycin and penicillin stimulated growth equally well. Previous work at the University of Alberta has shown that penicillin does not always increase the rate of gain of pigs (Hironaka '51, Experiment I and Experiment II - Trial B). Similar findings were reported by Gunha ('51) with pigs and Sauberlich ('52) working with rats.

The combinations or series of antibiotics did not appear to increase the rate of gain or improve feed efficiency above that of the best single antibiotic in the combination or series. A trend towards more efficient utilization of feed was found in some instances, but no antibiotic appeared to show any advantage over another.

Summary - Experiment III

1. Rate of gain was stimulated the most by aureomycin supplement and the least by bacitracin, with penicillin supplement in between.
2. Combining antibiotics or feeding them in series did not increase rate of gain above that obtained from the best single antibiotic supplement included in the combination or series.
3. A trend toward more efficient utilization of feed was indicated when antibiotic supplements were added to the ration.

SUMMARY AND CONCLUSIONS

1. Three experiments were conducted to study the addition of antibiotic supplements to swine rations.
2. The rate of gain was generally increased when an antibiotic supplement was fed in the ration. The increase was not statistically significant in all cases, and there was a wide variability in response. A carry-over effect in rate of gain was observed in one trial after the antibiotic was deleted from the ration.
3. Combinations of antibiotics showed no advantage over single antibiotics. This would indicate that the growth promoting effect of antibiotics is not due to changes in the microflora of the digestive tract. Aureomycin was found to be the most effective in promoting accelerated rate of gain with penicillin less effective and bacitracin having little effect.
4. A trend toward an increase in feed efficiency was found when antibiotic supplements were fed, but the increase was not marked.
5. Lower levels of protein in the ration during the growing period, resulted in a trend toward slower gains. Antibiotic supplements appeared to spare protein in one trial but not in a duplicate trial.
6. Pigs responded differently to antibiotic supplements with respect to the quality of carcasses which were produced. When the antibiotic was fed to 200 lb., there was a trend toward fatter carcasses and lower Advanced Registry scores. In some cases, carcasses from

pigs fed an antibiotic to 110 or 125 lb. in weight were fatter and had a smaller area of loin.

7. There was a greater shrinkage from hot to cold carcass weight in carcasses from pigs fed antibiotic than in those from pigs which did not receive any antibiotic. This would tend to indicate more water in carcasses from pigs fed antibiotic supplements.
8. Plasma lipid levels were not affected by antibiotic supplementation of the ration or by different levels of protein fed.
9. Significant correlations were found between plasma lipid levels and certain Advanced Registry measurements of the carcasses in one trial. Positive correlations were found with shoulder fat and thickness of loin, and negative correlations were found with area of loin and backfat score. In a duplicate trial conducted the following year no significant correlations were found.
10. Vitamin A and carotene storage in the liver was not affected by antibiotic supplement or by protein level of the rations.

LITERATURE CITED

ALLEN, N. N. 1938. Minn. Agr. Exp. Sta. Tech Bull. 130.

ALMQVIST, H. J. 1952. Amino acid requirements of chickens and turkeys -- a review. Poult. Sci. 31: 966.

BEACOM, S. E. 1951. A study of some constituents of the milk and blood: and the effects of the animal protein factor in swine nutrition. Master of Science thesis. Univ. of Alberta.

BEESON, W. M. 1952. Role of antibiotics in swine feed. Flour and Feed 53: 16, from Biol. Abs. 26: 7F, 1952.

BELL, M. C., C. K. WHITEMAIR and W. D. GALLUP. 1951. The effect of aureomycin on digestion of steers. Proc. Soc. Exp. Biol. Med. 76: 284, from Biol. Abs. 25: 3, 1951.

BERG, L. R., G. E. BEARSE, J. McGINNIS and V. L. MILLER. 1950a. The effect on the growth of fryers of adding an aureomycin fermentation product to a high energy fryer ration. Poult. Sci. 29: 629.

BERG, L. R., G. E. BEARSE, J. McGINNIS and V. L. MILLER. 1950b. The effect of removing supplemental aureomycin from the ration on the subsequent growth of chicks. Arch. Biochem. 29: 404.

BERL, S. and W. H. PETERSON. 1943. Determination and control of carotene and vitamin A in Wisconsin butter. J. Nutr. 26: 527.

BIRD, H. R. 1950. Antibiotics in feed. Feedstuffs 22: 10, from Biol. Abs. 25: 14, 1950.

BLIGHT, J. C., J. X. KING and N. R. ELLIS. 1952. Effect of vitamin B₁₂ and aureomycin concentrates on the growth rate of unthrifty weanling pigs. J. Animal Sci. 11: 92.

BOWLAND, J. P., S. E. BEACOM and L. W. McELROY. 1951. Animal protein factor and antibiotic supplementation of small grain rations for swine. J. Animal Sci. 10: 629.

BRIGGS, J. E. and W. M. BEESON. 1951. Further studies on the supplementary value of aureomycin, streptomycin and vitamin B₁₂ in a plant protein ration for growing-fattening pigs. *J. Animal Sci.* 10: 620.

BRIGGS, J. E. and W. M. BEESON. 1952. The effect of vitamin B₁₂, aureomycin, streptomycin or dried whey factor supplements on the growth and fattening of weanling pigs. *J. Animal Sci.* 11: 103.

BURGESS, R. C., M. GLUCK, G. BRISBON and D. H. LAUGHLAND. 1951. Effect of dietary penicillin on liver vitamin A and serum carotenoids in the chick. Letter to the editor. *Arch. Biochem.* 33: 339.

BROWN, J. A. 1952. The use of antibiotics in poultry rations. Master of Science thesis. Univ. of Alberta.

BURNSIDE, J. E., T. J. CUNHA, H. M. EDWARDS, G. B. MEADOWS, G. A. LAMAR, A. M. PEARSON and R. S. GLASCOCK. 1950. Response of the pig to APF, B₁₂ and B_{12b}. *Proc. Soc. Exp. Biol. Med.* 74: 173.

CARD, L. E. 1951. ----- *Feedstuffs* 23: 1.

CARLE, B. N. and W. H. DEWHIRST, Jr. 1942. A method for bleeding swine. *J. Am. Vet. Med. Assn.* 101: 495.

CARPENTER, L. E. 1950. Effect of aureomycin on the growth of weaned pigs. *Arch. Biochem.* 27: 469.

CARPENTER, L. E. 1951a. The effect of antibiotics and vitamin B₁₂ on the growth of swine. *Arch. Biochem.* 32: 187.

CARPENTER, L. E. 1951b. Effect of APF concentrate containing aureomycin on gestating, lactating and growing swine. *J. Animal Sci.* 10: 657.

CATRON, D. V., V. C. SPEER, H. M. MADDOCK and R. L. VOHS. 1950. Effect of different levels of aureomycin with and without vitamin B₁₂ on growing fattening swine. *J. Animal Sci.* 9: 652.

CATRON, D. V., A. H. JENSEN, P. G. HOMMER, H. M. MADDOCK and G. C. ASHTON. 1952. Re-evaluation of protein requirements of growing-fattening swine as influenced by feeding an antibiotic. *J. Animal Sci.* 11: 221.

CRAVIOTO-MUNOZ, J., H. G. PONCHER and H. A. WAISMAN. 1951. Vitamin B₁₂ sparing action of aureomycin in the rat. Proc. Soc. Exp. Biol. Med. 77: 18.

CUNHA, T. J. 1950. Latest developments on APF, B₁₂, aureomycin and related factors for the growing pig. Nutr. Conf., Tex. Agr. and Mech. Coll.

CUNHA, T. J., G. B. MEADOWS, H. M. EDWARDS, R. F. SEWELL, A. M. PEARSON and R. S. GLASSCOCK. 1951. A comparison of aureomycin, streptomycin, penicillin and an aureomycin-B₁₂ feed supplement for the pig. Arch. Biochem. 30: 269.

EDWARDS, H. M., T. J. CUNHA, G. B. MEADOWS, R. F. SEWELL and C. B. SHAWVER. 1950. Observations on aureomycin and APF for the pig. Proc. Soc. Exp. Biol. Med. 75: 445, from Biol. Abs. 25: 6, 1951.

EDWARDS, H. M., T. J. CUNHA, G. B. MEADOWS, C. B. SHAWVER and A. M. PEARSON. 1951. Effect of APF in supplying multiple factors for the pig. Proc. Soc. Exp. Biol. Med. 76: 173.

ELAM, J. F., L. L. GEE and J. R. COUCH. 1951a. Effect of feeding penicillin on the life cycle of the chick. Proc. Soc. Exp. Biol. Med. 77: 209.

ELAM, J. F., L. L. GEE and J. R. COUCH. 1951b. Function and metabolic significance of penicillin and bacitracin in the chick. Proc. Soc. Exp. Biol. Med. 78: 832.

HIRONAKA, R. 1951. Addition of growth stimulants to rations of growing swine. Animal Sci. 72, Dept. Animal Sci., Univ. of Alberta.

HOEFER, J. A., R. W. LUECHE, F. THIOPP, Jr. and R. L. JOHNSTON. 1952. The effect of terramycin on the growth of pigs fed different levels of protein. J. Animal Sci. 11: 455.

JOHNSON, L. P. V. 1950. An introduction to applied biometrics. Burgess Pub. Co., Minneapolis 15, Minn.

JUKES, T. H., E. L. R. STOKSTAD, R. R. TAYLOR, T. J. CUNHA, H. M. EDWARDS and G. B. MEADOWS. 1950. Growth promoting effect of aureomycin on pigs. Arch. Biochem. 26: 324.

LUECKE, R. W., F. THORP, Jr., H. W. NEWLAND and W. N. McMILLEN. 1951.
The growth promoting effect of various antibiotics on pigs. J.
Animal Sci. 10: 538.

McELROY, L. W. and R. T. BERG. 1951. Steer feeding trials. 1950-51. The
Press Bull. Univ. of Alberta 36(2): 1.

MCGINNIS, J., L. R. BERG, JOEL R. STERN, R. A. WILCOX and G. E. BEARSE.
1950. The effect of aureomycin and streptomycin on growth of
chicks and turkey poult. Poult. Sci. 29: 771.

MCGINNIS, J., JOEL R. STERN, R. A. WILCOX and J. S. CARVER. 1951. The
effect of different antibiotics on growth of turkey poult. Poult.
Sci. 30: 492.

MCMEEKAN, C. P. 1940. Growth and development of the pig, with special
reference to carcass quality characteristics. Part II. Effect of
the plane of nutrition on the form and composition of the bacon
pig. J. Agr. Sci. 30: 511.

MATTERSON, L. D. and E. P. SINGSEN. 1951. A comparison of several
antibiotics as growth stimulants in practical chick starting rations.
Coll. of Agr., Univ. of Connecticut. Bull. 275.

MONISON, W. J., L. S. DIETRICH and C. A. ELVEMJEM. 1952. The effect of
different carbohydrates and antibiotics on the growth of chicks
and the storage of vitamins. J. Nutr. 46: 411.

MOORE, P. R., A. EVENSON, T. D. LUGHEY, E. MCCOY, C. A. ELVEMJEM and
E. B. HART. 1946. Use of sulfasudine, streptothricin and
streptomycin in nutritional studies with the chick. J. Biol. Chem.
165: 437.

NOLAND, P. R., D. L. TUCKER and E. L. STEPHENSON. 1952. Subcutaneous
implantation of bacitracin in pellet form to stimulate growth of
suckling pigs. Agr. Expt. Sta., Univ. of Arkansas. Report series 34.

SAUBERLICH, H. E. 1952. Effect of aureomycin and penicillin upon the
vitamin requirement of the rat. J. Nutr. 46: 99.

SHEFFY, B. E., R. H. GRUEDER, P. H. PHILLIPS and G. BONSTEDT. 1952.
Comparison of growth responses of 2-day-old pigs to streptomycin,
aureomycin and crude APF alone and in combination with B_{12} . J.
Animal Sci. 11: 97.

- SIEBURTH, J. M., J. GUTIERREZ, J. McGINNIS, JOEL R. STERN and B. H. SCHNEIDER. 1951. Effect of antibiotics on intestinal microflora and on growth of turkeys and pigs. Proc. Soc. Exp. Biol. Med. 76: 15.
- SMITH, DOROTHY G. and H. J. ROBINSON. 1945. The influence of streptomycin and streptothricin on the intestinal flora of mice. J. Bact. 50: 613.
- SPEER, V. C., R. L. VONS, D. V. CATRON, H. N. HEDDOCK and C. C. CULBERTSON. 1950. Effect of aureomycin and animal protein factor on healthy pigs. Arch. Biochem. 29: 452.
- STERN, JOEL R. and J. McGINNIS. 1950. Antibiotics and early growth of rats fed a soybean oil meal diet. Arch. Biochem. 28: 364.
- STOKSTAD, E. L. R., T. H. JUKES, J. PEARCE, A. C. PAGE, Jr. and A. L. FRANKLIN. 1949. The multiple nature of the animal protein factor. J. Biol. Chem. 180: 647.
- TERRIL, S. W., D. E. BECKER, C. R. ADAMS and R. J. MEADE. 1952. Response of growing-fattening pigs to bacitracin, aureomycin and other supplements. J. Animal Sci. 11: 84.
- WEBER, E. M., H. G. LUTHER and W. M. REYNOLDS. 1952. Bull. World Health Organ. 6: 149.
- WHITEHILL, A. R., J. J. OLESON and B. L. KITCHINGS. 1950. Stimulatory effect of aureomycin on the growth of chicks. Proc. Soc. Exp. Biol. Med. 74: 11.
- WHITLOCK, G. P. 1952. The role of antibiotics in livestock and poultry nutrition. Nutr. Conf., Mont. State Coll.

B29766